HOUSEHOLD COOKING FUEL USE PATTERNS AND DETERMINANTS ACROSS SOUTHERN AFRICA: EVIDENCE FROM THE DEMOGRAPHIC AND HEALTH SURVEY DATA

Abstract

Improving access to modern energy sources is critical to enhancing the quality of life of many people in developing countries. In southern Africa, the majority of rural and poor urban households are dependent on solid fuels to meet their cooking needs. This has adverse effects on health, productivity, and environmental sustainability. To date, there is scarce information in the literature on household cooking fuel patterns and choice determinants across the southern African region. Using household fuel data from the Demographic and Health Survey (DHS), this study investigated cooking fuel types and the determinants of their choice by households in selected countries in sub-Saharan Africa. The data on household cooking energy were subjected to descriptive and inferential statistics. Results show that 25% of sampled households in all seven countries have access to electricity, while 66% rely on biomass for cooking. Chi-Square analyses revealed a statistically significant relationship between place of residence and type of cooking fuel, and between access to electricity and type of cooking fuel. Results from multiple regression analysis showed that socio-demographic factors such as access to electricity, household size, level of education, and wealth index have a positive influence on the type of cooking fuel used in this region. However, access to electricity does not imply that households will negate the use of traditional fuels. These results have implications **for** household air pollution, health, policy and environmental sustainability. It is recommended that energy interventions in this region need to consider demand factors and have to be less supply driven, advocating for continued use of multiple fuels from a suite of options.

Key words: Households, choice determinants, cooking fuel, environmental sustainability, southern Africa

1.0 INTRODUCTION

Energy provision is essential for human survival and an integral aspect of environmental management. Access to clean, affordable and efficient energy has become a challenge for the majority of low to medium-income households in developing countries.[1] This has been a cause of global concern for international agencies and researchers in the fields of human health and environmental management. Globally, approximately 3 billion people rely on solid fuels such as biomass, coal, and animal waste to meet their basic energy needs.[2] These fuels are combusted in poorly designed and inefficient cookstoves resulting in emissions of noxious gases and products of incomplete combustion (PIC).The continued use of solid fuels has been linked to increased morbidity and mortality.[3] The WHO Global Health Observatory has reported that in 2012 household air pollution (HAP) caused 4.3 million premature deaths worldwide, while ambient air pollution caused a further 3.7 million deaths.[4] HAP is associated with many health effects such as acute and chronic respiratory disorders, pulmonary and systemic diseases.[5] Acute respiratory infections are considered the number one killer of children under the age of five.[6,7] In South Africa, acute lower respiratory infections accounts for approximately 14% of deaths amongst children under five years and **are ranked**, together with diarrheal disease, as one of the top killers of young children.[8,9]

According to recent data, about 1.4 billion people, globally, are without access to electricity.[10-12] In Africa, **a large concentration of people** (600 million people) have no access to electricity **and rely on traditional forms of energy sources to meet their basic energy needs**. **IRENA [13] was of the opinion that** 700 million **people on the African continent** were living without clean cooking energy. **Firewood remains a survival commodity for the majority of households i**n **Sub-Sharan Africa (SSA)**, a region that has the lowest total Gross Domestic Product (GDP) and GDP per capita in the world.[14, 15] According to a GIZ report ,[12] 90% of rural households across SSA relied on biomass as their primary energy source for cooking and heating.[12,16] **For example, Howels et al. [19], Bailis et al. [20], and Mekonnen et al. [21] indicated that the use of firewood for cooking and heating was common in countries such as Malawi, Zimbabwe, Ghana, Nigeria, Gabon, Angola and South Africa.** For urban households in SSA, Zulu and Richardson[17] **highlighted charcoal as** a major source of household energy **as it provided** an important source of household income; **charcoal is a** renewable energy source that has the potential to power economic growth while reducing dependency of poor developing countries on costly energy imports. An added advantage of using charcoal over firewood is that charcoal has higher energy content per kg of fuel burned, is less bulky and easier to store and transport, and burns with less smoke emissions.[18] **However, the greater time needed for harvesting, preparing, and transporting the fuels reduces opportunities for productive work and education in women and children [Ekholm et al., 2010]. Pachauri**

(2004) was of the opinion that the issue of relying on firewood has a gender and equity dimension, as most of the adverse effects of domestic cooking using firewood (i.e. exposure to smoke particles, sexual violence, and back injuries) are evident in women and children (Adkins).

Electrification (rural and urban) has received much attention in different countries in southern Africa, with South Africa having the highest electrification rates of up to 87% [ref]. However, in many of the countries, electricity is rarely used for cooking. For example, a research carried out in the Bushbuckridge region of South Africa showed that 10 years after receiving electricity with a free basic electricity policy of 6 kWh per month, over 90% of households still used firewood for cooking and heating [Madubansi and Shackleton, 2008]. The free basic electricity policy was put in place when the government realised that the increase in the electrification process would not automatically result in meaningful levels of electricity consumption by poor households due to diverse socio-economic dynamics [Mapako and Prasad, 2004]. However, Makonese et al. 2011 argued that that the quantity of free basic electricity provided to poor households was inadequate to meet basic needs and improvement of quality of life, and they proposed a minimum of 200 kWh per month per indigent household. Thus, electrification cannot be taken as a sole effective solution to reduce the consumption of traditional fuels and reduce impacts associated with their continued use [Ekhol et al., 2010]. According to Kanagawa and Nakata [2008], in poor households electricity is needed for lighting and refrigeration, and this has been associated with improved education and employment possibilities.

There is extensive information in the literature pertaining to household cooking energy requirements for developing countries [Ekholm et al, 2010]. The studies have asserted the 'energy ladder' as a key model, which influences choice of household cooking fuels [Hossier and Dowdy, 1987; Leach, 1992; Smith et al., 1994]. According to the 'energy ladder' model, households tend to switch to more convenient and less polluting energy carriers as their disposable income increases [Ekholm et al., 2010]. However, this school of thought has received some critics in recent years – Masera (2000) observed that in rural Mexico, households do not ascend the 'energy ladder' with an increase in disposable income. Rather, they 'stack' fuels, where traditional fuels are not discarded completely but used together with modern fuels due to cultural preferences [Ekholm et al., 2010]. Contrary to initial assertions of the 'energy ladder' model highlighting a single-fuel substitution pattern, it has become apparent that fuel 'stacking' is the norm in most households [Arnold et al., 2006; Hiemstra-Van der Horst and Hovorka, 2008; Trac, 2011; van der Kroon et al., 213]. Heltberg (2003) posited that there is a lot of fuel 'stacking' in the urban communities compared to rural communities that the prospect for modern fuels to combat indoor air pollution is better in urban than in rural areas.

Although income plays an important role in determining the choice of household cooking fuels used, evidence in SSA has shown that there are no clear-cut linkages between income level and fuel type. In fact, Arnold (2006) was of the opinion that the effect of income on fuelwood consumption was small and that the few observed income elasticities were significantly different from zero. On the other hand, Hiemstra-Van der Horst and Hovorka, (2008) argued that case studies across SSA revealed that fuelwood can be an important energy source for households at all levels of wealth. These studies were carried out in Mozambique (Brouwer and Falcao, 2004), Zimbabwe (Campbell, 2003), Kenya (Milukas, 1993), Tanzania (Hosier and Kipyonda, 1993), Nigeria (Odihi, 2003) and Chad (van der Plas and Abdel-Hamid, 2005). This shows that although income levels play role in shaping fuel choices in the surveyed countries, many other factors such as level of education and place of residence also matter (Heltberg, 2003). Thus, the factors likely to affect fuel choices vary by geographical location, wealth and household preferences (Ekholm et al., 2010).

A number of studies on household cooking fuel uses and fuel determinants have been carried out in different parts of the world including in Ethiopia[21], India[24], Guatemala[25], Burkina Faso[26], and Zimbabwe [27]. However, a review of the literature has shown that limited studies have been conducted to provide inter-national level profiles in terms of types of **household** cooking fuel and fuel choice determinants in **southern Africa**.[23,28] Currently, there is a dearth of information on multi-country household cooking fuel use scenarios in sub-Saharan Africa, except for a report by Merven *et al.*[28], which modelled energy future demands in the Southern African Development Community (SADC) region. In light of the above, the most recent Demographic and Health Survey (NDHS) **data** of seven countries in **southern** Africa were employed to **investigate cooking fuel types and the determinants of their choice by households in selected countries in sub-Saharan Africa**, as well as their implication **for** environmental sustainability. To meet the main aim of the study, three research questions were formulated as follows: i) **What is the distribution of household cooking fuel types and access to electricity in selected countries in the southern African region?** ii) **Is there any statistical significant relationship between place of residence and type of household cooking fuel?** iii) **Is there any statistical significant relationship between access to electricity and type of household cooking fuel? iv) Can socio-economic characteristics predict household types of fuel used for cooking? To address the research questions, DHS data were subjected to both descriptive and inferential statistics using SPSS 20 software.**

2.0 DATA SOURCE AND ANALYSIS

The data used for this analysis were drawn from Demographic and Health Surveys (DHS) of seven countries from southern Africa. DHS are country specific household surveys carried out by ICF Macro/MEASURE DHS on behalf of national ministries of health, through funding from the United States Agency for International Development. The countries selected for this study include Angola (2011), Lesotho (2009), Malawi (2012), Namibia (2007), Swaziland (2006), Zambia (2007), and Zimbabwe (2011) (see fig.1). Only current data sets were used for each country; earlier measurements were omitted, as some country information did not have data on some indicators. Given the focus of our work, we obtained nationally and sub-nationally representative household energy use data as well as other household characteristics that include gender, age, educational background, place of location, access to electricity, and wealth index. The DHS are a key source of comparative quantitative data across developing countries on demographic and health indicators covering both rural and urban populations. The data were analysed using the IBM SPSS 15 version for frequency, percentage, chi-square and logistic regression. A probability level of 0.05 was used for all tests of significance. As this study is based on secondary analysis of existing DHS data that are in the public domain, ethical clearance from the University of Johannesburg was not required.

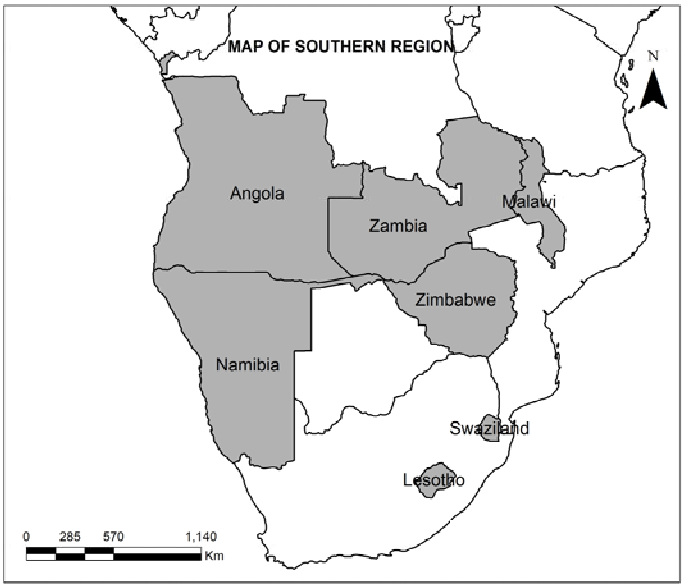

Fig. 1: Map showing the seven countries selected for the study

3.0 RESULTS AND DISCUSSION

3.1 Distribution of Urban and Rural Households Surveyed

Table 1 shows the proportional distribution of households **sampled in the study**. From Table 1, 69.5% of surveyed households live in rural areas and 30.5% in urban communities. From the selected seven countries, only 25.5% households have access to electricity, while 74.5% responded in the negative. With respect to the type of cooking fuel used, fuelwood is the most dominant type of fuel (66.5%), followed by **liquefied petroleum gas (LPG) (8.8%), electricity (8.6%), and charcoal (7.4%)**. This means that 74% of households surveyed rely on biomass fuels to meet their basic energy needs. Only 1.9% and 1.4% of households used natural gas and kerosene, respectively.

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The findings agree with reports of various international organisations such as IEA[29]; IRENA[13] and WEC[30]. These reports documented that biomass fuels (firewood and charcoal) are widely used by the majority of households in sub-Saharan Africa for cooking and heating. According to IEA (2014:5)[29], "*bioenergy, mostly fuelwood and charcoal, accounts for more than 60% of energy demand…access to modern energy is very limited, more than 620 million people (two-thirds of the population) in sub-Saharan Africa are without access to electricity. Nearly 730 million rely on the traditional use of solid biomass for cooking*".

Table 2 shows percentage distribution of household with access to electricity across the seven countries. The results show in all the countries access to electricity in the sub-region is very low. More than 80% have no access to electricity most of whom lives in the rural areas. This result **indicates** that access to electricity is area dependent as shown in Table 2, where the majority of those in urban areas have **access to electricity**. The average rate of access to **electricity in urban areas** in these countries can be put at 78.5% of the total number of households and less than 20% in rural areas.

INSERT TABLE 2 HERE!

The distribution of different types of fuel used country-by-country is shown in Table 3. In Angola, the dominant type of fuel used for cooking is LPG (42.2%), followed by fuelwood (39.7%) and charcoal (14.5%). Electricity, kerosene, and straw/shrub/grass are seldom used. In Lesotho, 27.6% households used the following modern fuels for cooking – LPG (11.9%), electricity (4.4%), kerosene (6.5%) with 72% relying on tradition biomass fuels such as firewood, animal dung, agricultural crop and straw/shrubs/grass. In Malawi, 3.8% households used electricity for cooking, while 96% were dependent on biomass (i.e. firewood – 78.4% and charcoal – 17.4%) for purposes of cooking and heating. In Namibia, 97% of surveyed households used biomass fuels for cooking and space heating; only 1.2% and 0.7% used natural gas and electricity, respectively. In Swaziland 14.3% of the surveyed households used electricity as a primary source of energy, while 11.8% used natural gas for cooking and water heating purposes. Kerosene is used by 3.6% and firewood is used by 69.2% of the surveyed households. In Zambia, more than two-thirds of households used firewood (58.1%) and charcoal (26.9%), respectively. The percentage of households that use electricity for cooking is 14.6%. In Zimbabwe, 72% of the surveyed households were dependent on firewood, with 26.4% using grid electricity for cooking and water heating needs (Table 3). These findings are consistent with a study conducted by Merven *et al.*[28] across several countries of sub-Saharan Africa. In the study, it was reported that few households used modern fuels such as LPG and electricity for cooking. The majority depends on traditional biomass fuels such as firewood and charcoal. Malakai *et al.*[31] reported that firewood and charcoal contributes over 90% of Malawi's total energy demand. According to the government of Malawi[32], energy sources **such as solar, hydro, wind, geothermal, kerosene, and coal** play a minor role in energy demand and only account for 7% of **total** energy use.[32] The IEA[10] reported that up to 95 percent of people in developing countries, **including countries in Africa,** rely on solid fuels (biomass fuels and coal) to meet their energy needs.

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Table 4 shows that firewood is a major source of energy for cooking among rural households in all the countries investigated, while electricity and kerosene are commonly used by urban households. Country-by-country analysis shows that the majority of urban households (88.8%) in Angola used LPG for cooking, followed by charcoal (7.9%). In rural communities, firewood and charcoal are used by 70.6% and 19.9% households, respectively. An interesting find is that of all the sampled rural households ~8% used LPG for cooking. According to an IEA[33] report, firewood is mostly used in rural areas, while charcoal is preferred in peri-urban areas, due to its lower transport weight. Most of the unsustainable use of biomass in Angola appears to emanate from the felling of trees for purposes of making charcoal to supply **to** peri-urban areas. Electricity supply for both rural and urban communities remain low because existing infrastructure in the electricity sector was built well before independence (i.e. 1975), and has not received routine maintenance since. Much of this infrastructure was destroyed during the civil war, and could not be rebuilt and maintained in part due to war related access problems. Consequently, only a small percentage of the population has access to grid electricity and the service is generally unreliable.[33] Improving access to electricity services and other renewable energy technologies such as solar and geothermal is critical to Angola's economic and human development.

In Lesotho, while 60.9% rural households rely on firewood as fuel, it accounts for 9.6 % of the energy demand in urban areas. A UNECA report[34] highlights that biomass is used by approximately 90% of rural households to meet both cooking and thermal energy needs. The over-exploitation of biomass resources has far- reaching consequences on biodiversity and forest resources resulting in land degradation and deforestation. In this study, LPG and electricity are used by 37% and 19.6% households in urban areas of Lesotho, respectively. About 6.5 % households use LPG and 1.2% of households use electricity in rural areas. The energy sector in Lesotho suffers from inadequate financing from the government resulting in lower electrification rates. As such, there are challenges in financing energy projects including increasing power generation and investing in renewables.

Because the country has no coal reserves, the coal used in power generation is purchased from South Africa. This has a knock on effect on the price of electricity – the electricity tariffs are generally inflated resulting in the majority of people relying on biomass fuels.

In Malawi, fuelwood is used by 97% of households in rural areas, **with large amounts of firewood processed into charcoal for convenience of use**. This finding is consistent with Jumbe and Angelsen[35] submission that biomass energy accounts for more than 90% of the total primary energy consumption, and forests contribute nearly 75% of the total biomass supply. According Malakai *et al*.[31], this high dependence on firewood and charcoal is due to easier access and affordability of the fuels compared to other forms of energy. Malinski[36] is of the opinion that high population density coupled with low per person agricultural productivity has far-reaching consequences on the environment and the health of the rural inhabitants. Malinski further contends that deforestation in Malawi is increasing at a rate of ~3.2% and firewood is becoming a scarce commodity, with forest reserves having declined from 47% to 28% in the past 25 years. In Namibia, 2.4% of the surveyed urban households use electricity to meet their basic energy needs. Natural gas plays a significant role in the urban energy mix. Evidence suggests that natural gas is readily used in the urban areas compared to electricity. Charcoal and wood were used by over 90% households in both rural and urban communities. This heavy reliance on woody biomass for cooking and heating has detrimental effects on the environment and the health of the end users.

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In Swaziland, Zambia and Zimbabwe, the urban communities rely on electricity to meet their basic energy needs. Zimbabwe records the highest electricity access and use in urban areas at 77%, followed by Swaziland at 41% and Zambia at 34%. There is more electricity usage in the rural communities of Swaziland than in urban Namibia (Table 4). Although there is a higher reliance on electricity in the urban areas of Zimbabwe, the service is frequently erratic resulting in some households going for longer periods without electricity.[37] A large percentage (29%) of the urban populace in Namibia use natural gas to meet their energy needs. In Lesotho and Zimbabwe, urban households rely on kerosene to meet their cooking and heating needs. This is because of the electricity supply woes in both countries forcing households to use other alternative energy sources. Kerosene is readily available, cheap, easy to use, and does not require expensive and complicated household combustion devices to burn it. In Zambia there is an over reliance on charcoal (53%), especially in peri-urban areas compared to only 13% for firewood. For the three countries, the majority of rural households rely heavily on firewood to meet their energy needs: Swaziland (87%), Zambia (88%) and Zimbabwe (95%). A significant proportion of the woody biomass harvested in these areas is sold to urban dwellers. Urban households in Angola, Malawi and Zambia used charcoal than their counterpart from other countries in the study. It was also found that the chi-square value observed for each country with a p-value of 0.001 shows a statistically significant relationship between household type of place of residence and the type of fuel use at the 0.01 level.

Table 5 indicates the descriptive statistics – cross-tabulation of access to electricity and type of cooking fuel across countries. In all countries, all households without access to electricity used firewood and charcoal as fuel for cooking. Among those with access to electricity, only in Zimbabwe (77.4%) and Zambia (77.1%) has majority of households using it for cooking. Only 36.4%, 25.1% and 44.6% respectively of those with access to electricity used it for cooking in Lesotho, Malawi and Swaziland. In Angola, LPG is the major fuel used by 89.3% households with access to electricity while in Lesotho LPG is used by 32.2% of households with electricity. The implication is that not all households with electricity used it for cooking. This could be due to the cost of electricity, which is relatively higher than other fuel type. Furthermore, the non-usage of electricity for cooking by many households especially in the rural areas can be **explained by lack** of access to electricity. It was also observed that natural gas is not used by households in Angola, Malawi and Zambia. However, 10% of households in Lesotho, 5.1% in Namibia, and 22% in Swaziland of those with access to electricity used natural gas. Meanwhile only 6.9% of households without and 4% of households with electricity in Lesotho used kerosene for cooking. The chi-square value observed for each country with a p-value of 0.001 shows a statistically significant relationship between household access to electricity and the type of fuel used at the 0.01 level.

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3.2 Determinants of Household Fuel Choice

A stepwise multiple regression analysis was conducted to evaluate whether socio-demographic variables will be able to predict type of cooking fuel used by household within the region. The prediction model contained all the predictors with no variables removed. The model was statistically significant, F (7, 120600) = 1571.115, $p < 0.001$, and accounted for approximately 84% of the variance of type of cooking fuel (R^2 = .0.084, Adjusted R^2 = 0 .084). From the model summary in Table 6, it is clear that that the variables included in the model together predict significantly households' use of certain cooking fuel. Multiple regression results indicate household income, number of household member, place of residence, access to electricity; wealth, educational level, and age of head of household are important factors that influence fuel type use in the Southern Africa region. Access to electricity has the strongest weight in the model followed by highest education, wealth; household size has the lowest of the seven weights. The variance explained by each of the variables was: access to electricity 63%; highest education 14%; wealth index 4%; while age of head of household, sex of head of household, type of place of residence, and household size has 1% variance respectively. It can be inferred that electricity and highest educational level were very strong positive predictors of type of cooking fuel used by households.

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Table 7 shows the results of the multiple regression analysis when conducted on country-by country with the demographic variables and type of cooking fuel. It shows the joint effects and the relative contributions of each variable on the type of cooking fuel. The results for Angola show that the predictor variables have significant influence on the type of cooking fuel of households (Table 7). The analysis shows that R = 0.749, the adjusted R^2 = 0.559 and F-value = 547.758 is significant at 0.001, a level that is less than 0.05. This implies that 56% of the variance in the type of cooking fuel of households is accounted for by the predictor variables. Wealth index, access to electricity and type of place of residence were predictor variables that significantly determine the type of cooking fuel of households.

In Lesotho, the predictor variables related to type of cooking fuel of households fuelwood were statistically significant with R = 0.748, R^2 = 0.560; Adjusted R^2 = 0.558 and F value = 360.210. The multiple regression results indicate household income, number of household member, place of residence, access to electricity; wealth, educational level, and age of head of household are important factors that influence fuel type use in the Lesotho. Multiple regression results for Malawi shows that two variables (access to electricity and type of place of residence) were found to be predictors and accounted for 3.9% of the variance in the type of cooking fuel of households. In Namibia, three variables (highest education, access to electricity, and type of place of residence) were found to be predictors of household cooking fuel. The three variables put together contributed (R^2 = 0.019) of the variance in the percentage of households cooking fuels.

For Swaziland, the results of the regression reveal that **six variables:** wealth index, access to electricity, type of place of residence, household size, educational level and sex of household head are the best predictors of type of household cooking fuel use. These six predictor variables explained 38.8% of the variance in household cooking fuel use. **In Zambia**, the results indicate that five variables including wealth index, access to electricity, type of place of residence, household size, and educational level are the best predictors of type of household cooking fuel use. These five predictor variables explained 72.6% of the variance in household cooking fuel use. For Zimbabwe, four variables including access to electricity, type of place of residence, household size, and educational level are the best predictors of type of household cooking fuel use. These four predictor variables explained 32.7% of the variance in household cooking fuel use. These findings are consistent with other studies[21,25,38,39] in the literature that socio-demographic factors such as wealth index, education, place of residence, access to electricity are important in determining households' choice of cooking fuel.

INSERT TABLE 7 HERE!

4.0 CONCLUSION AND IMPLICATIONS OF THE FINDINGS

This study focused on household type of cooking fuel use and determinants of choice in seven southern African countries. Data used were sought from the DHS survey. The results have shown that **the majority** of households in the region use firewood as cooking fuel. In rural areas across the countries, surveyed firewood use was high which can be attributed to lack of alternative, high cost of electricity and low of cost or free firewood. Findings from the study indicated that significant **relationships** exist between place of residence and access to electricity and the type of cooking used in all the countries. We also found that household characteristics, such as access to electricity, educational level, wealth, sex and age of household, place of residence and household size are important determinants of the choice of the type of cooking fuel to use.

Clearly, these findings have great implications not just for the environment sustainability but also for **human health and education**, which must be appreciated. First, the continued use of firewood will no doubt put pressure on forest resources in these countries, which will lead to deforestation, loss of biodiversity, soil erosion and destruction of the habitat of animals. Furthermore, the consideration for quality of air and changes in the climate are inevitable. The increase in carbon dioxide and methane in the atmosphere is the result ~~s~~ of the burning of fossil fuels, reduction of carbon dioxide absorption due to indiscriminate destruction of the forest. Globally, biomass burning constitute largest source of trace gases in the atmosphere. [40,41] **According to IEA**[42], in 2009, in sub-Saharan Africa, charcoal production led to 14% (29,760 km^2) of total deforestation and 76 million tons of carbon, which is about 96% of total greenhouse gases from biomass energy production. Sustainable biomass extraction could reduce GHG emissions by 36%.

Several studies on climate change have predicted negative impacts for sub-Saharan Africa (SSA). Evidence of which are already been felt; higher temperatures, increased evaporation, decrease in rainfall causing shortage, drying up of soils, increased pest and disease pressure, increased desertification in the Sahara region, floods, deforestation, and erosion.[43-45] According to Kofi Annan, former Secretary-General of United Nations in 2006, "*The impact of climate change will fall disproportionate on the world's poorest countries, many of them here in Africa. Poor people already live on the front lines of pollution, disaster, and degradation of resources and land. For them, adaptation is a matter of sheer survival*".[1]

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[1] Former UN Secretary-General Kofi Annan, addressing the Twelfth Conference of the Parties to the UNFCCC, Nairobi, Kenya, 15 November 2006.

There is a rapidly growing demand for biomass fuels in most urban communities in SSA and this imposes impacts on the resources in supply areas and on the livelihoods of suppliers and users.[46] Although the charcoal market provides urban households with an affordable, convenient and reliable source of energy and associated energy services[17] at reasonable prices, the continued use of this energy carrier has long-term negative impacts on forest resources. It has been argued that agricultural activities are one of the major factors affecting deforestation compared to harvesting fuel for energy use.[41,47-49] However, it is now clear that the production of charcoal is resource intensive, needing on average 8 kg of wood to make 1 kg of charcoal[47], and has the potential to cause localised deforestation. The use of charcoal has been linked to localized deforestation around cities such as Addis Ababa, Dar es Salam, Lusaka, Maputo, Lilongwe, and Dakar, and associated environmental degradation including soil erosion resulting in lower agricultural productivity.[17,50,51]

Another implication relate to the health of the people and animals. Carbon monoxide is poisonous to human and animals. Cooking with biomass solid fuels on open fires or coal burning stoves have been shown to be harmful to human health especially rural households in developing countries.[17,18] It has been reported that ambient air pollution levels and personal exposure levels from cooking with traditional fuels are severely high.[52] Charcoal fuel can pose other kinds of health risks and have negative impacts on forest. Negative health impacts at the site of charcoal production include inhalation of noxious gases and carbon monoxide poisoning.[17,18] In 2010, two million deaths, including over 1 million deaths from chronic obstructive pulmonary disease, and another million deaths from pneumonia in children under the age of 5 was caused by indoor pollution.[53,54] The World Health Organization (WHO) estimated that 4.3 million people die annually from sickness directly attributable to indoor air pollution from the use of solid fuels.[55]

These findings have important implications for energy policies in sub-Saharan African countries, especially if the energy interventions are based on the energy ladder model. Results show that households do not simply change "from traditional fuels to more modern and sophisticated energy sources with each improvement in disposable income. It can be argued that multiple energy sources are used such that modern fuel uptake largely complements traditional fuels such as biomass and kerosene, instead of permanently replacing them and preventing further use. Most households in sub-Saharan Africa are sensitive to the economic dynamics of increased modern fuel prices and start-up costs, such that they prioritise energy spending economy over convenience.[56] As such, modern fuel uptake **should not be taken to directly translate to a complete substitution** of biomass fuels. For example, it has been argued in Mangizvo[57] that most villages in rural Zimbabwe prefer food dishes such cow heels/trotters, offal, and *sadza* (thick maize meal porridge) cooked on a wood fire. Thus, even households with access to modern forms of energy would continue to use traditional fuels. Although income plays an important role in accessing modern energy and related technologies, it is not the sole driver of fuel choice patterns in this region. Other factors including socio-cultural aspects, household characteristics, and socio-economic aspects (level of education, age, and wealth) play a significant and intricate role. However, these factors are interconnected in a complex way that it becomes virtually difficult **to isolate one factor** as the sole causality.

Evidence from this study indicates that policies formulated based on the energy ladder model will not be effective in SSA in resolving issues pertaining to the continued use of traditional fuels (environmental degradation and health consequences). Instead, any energy interventions in the region should focus on providing households with a suite of efficient energy (multi fuel) options (from biomass fuels to electricity) and related novel technologies (e.g. improved cookstoves) from which to choose. Such a model would ensure that households continue to use fuels of choice, however, more efficiently than before, thereby ensuring environmental sustainability and health improvements. Despite widespread ability to afford commercial fuels, households should not be constrained to a single energy source, which may not address all energy needs of the household. Householders have the "right" to choose what energy sources to use, when, and how, without having the government or funding agencies imposing on them. Thus, energy interventions in this region need to consider demand factors and should be less supply driven, as supply does not always lead to uptake.

The results of this study show that better education for household heads would bring a shift and reduce the chances of choosing traditional fuel sources, to modern fuel like LPG. Education is a pivotal strategy for addressing the increasing problems of the human environment. The Sustainable Development Goals identified education as goal 4, "*Ensure inclusive and equitable quality education and promote life-long learning opportunities for all*". Again, Chapter 36 of Agenda 21, the Rio outcome document recognised the crucial role of education in achieving sustainable development[58] and as Mekonnen and Köhlin[21] observed, that as education increases the chance of using electricity or kerosene as main source of fuel. This comes to show that through education households possibly become more aware of the advantages of using cleaner fuels or at least learn of the disadvantages of biomass. Lack of awareness and education, therefore, can lead to prolonged biomass use as primary fuel.[59] Households are often not aware of the negative externalities that arise from biomass use and the benefits that accompany modern fuels. Awareness campaigns and public education can play an important role in promoting the switch to alternative cooking methods.

Acknowledgement

We are grateful to the Measure DHS, ICF International, Rockville, MD, USA for providing the DHS data of the countries for this analysis. The authors would also like to thank the University of Johannesburg for financial support through the URG post-doctoral research fellowship grant to AI and TM.

Conflict declaration

Authors declare no conflict

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